YATES

The Three-Hinged Ross-Drive Concrete Arch Bridge, Washington, D. C.

Civil Engineering

B. S.

1911

THE THREE-HINGED ROSS-DRIVE CONCRETE ARCH BRIDGE, WASHINGTON, D. C.

BY

ROBERT RALEIGH YATES

THESIS

FOR THE

DEGREE OF

BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1911

UNIVERSITY OF ILLINOIS

May 25, 1911

This is to certify that the thesis prepared under my personal supervision by ROBERT RALEIGH YATES entitled The Three-Hinged Ross-Drive Concrete Arch Bridge, Washington, D. C., is hereby approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

Ira O. Baker.

Head of the Department of Civil Engineering.

PREFACE

The writer chose the subject under discussion for a thesis because of his familiarity with the design and construction of the Ross-Drive Bridge. He was employed in the office of the Engineer of Bridges, District of Columbia, in 1907 and 1908, and worked both on the design and in the field.

CONTENTS

LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

The Three-Hinged Ross-Drive Concrete Arch Bridge is located in Rock Creek Park, Washington, D.C., and is about six miles from the center of the city, the White House approximately occupying that position. Construction was begun June 12, 1907; and the structure was completed on Nov. 11, 1907. The construction was not let to a contractor, but done by day labor under the supervision of the District of Columbia Engineer Department.

GENERAL DESCRIPTION OF SITE--Rock Creek Park is one of the most beautiful natural parks in the world and is one of the attractive features of our National Capital. This park contains nearly 1900 acres, and comprises a narrow strip of land on either side of Rock Creek for a distance of nearly 9 miles. The land was condemned by the United States government in 1894, and paid for out of the general District of Columbia Appropriation, and is maintained by the same source. Through-out its entire length, there are macadam roads for automobiles and carriages, besides many bridle paths. These are all kept in high-class condition, for the park may almost be called the "play-ground" for our Presidents and the Diplomatic Corps stationed at Washington, and is one of the first places shown to our distinguished foreign visitors. Rock Creek lies in a valley, flanked on both sides by all varieties of trees and foliage, and the bed and banks of the

stream are thickly dotted with large boulders in all their majesty of natural beauty.

The roadways require many bridges, both over Rock Creek and intersecting small streams, and these bridges are designed to harmonize as far as possible the artificial construction with the natural attractiveness of the surroundings, so as to avoid the formal aspect so common in many city parks. The bridges for the most part are of concrete, each one conforming with the peculiar conditions of the site, a "Boulder Bridge" over a stony run, a pebble-dash arch over a gravelly creek, and a tooled-finished bridge, the Connecticut Avenue Bridge, near the more thickly populated entrance.

The Ross-Drive Bridge is located in a thickly wooded gorge approached on each side by a macadam roadway. The site is about 300 yards west from Rock Creek. The design was made with the surroundings taken into consideration, and has since completion fulfilled the artistic as well as practical prophesies of the engineers.

GENERAL DESCRIPTION OF STRUCTURE.--This bridge was one of the first, if not the first, three-hinged concrete arched bridges built in America, using pins and pin shoes; and besides, the structure has many other novel features. The general design is shown in Plates 1 and 2.

The length over all is 163 ft. 2 in., and consists of a central arch of 100-ft. span and two 30-ft. approaches. The roadway is 16 ft. from curb to curb.

The arch consists of three ribs, 2 ft. wide, 2 ft. 6 in. deep at the crown and 3 ft. deep at the haunches. The deepest

part of the arch is 18 ft. away from the springing line, where it is 3 ft. 9 in., a surprising dimension when compared to the depth at the haunch, yet the reasons for such will appear in Chap. III. The arches are hinged at crown and haunches by special cast steel hinges shown in detail on Plate 5. The steel pins are of 4 in. diameter. The hinges are held in place by special reinforcing anchor rods shown on Plate 2, these rods extending part way into the arch but are not sufficiently long to designate the arch itself as a reinforced arch. The end of the rod extending through a hole in the pin-shoes is threaded and the shoe is bolted tight Between the arch ribs are four struts, which also act as flower troughs. The details are shown on Plate 9. The 5/8 in. reinforcing rods extend through the three ribs. The struts or troughs are to be filled with earth and to have planted in them some species of clinging vine, which in time will entwine the entire arch ribs and columns.

The road-bed over the arch is of macadam, 6 in. deep at the curb and 9 in. at the crown, resting on a 6 in. reinforced slab, which is carried by longitudinal girders 12 in. wide by 12 in. deep. The details are shown on Plate 7. There are no transverse girders as the slabs were considered sufficiently stiff for the 6 ft. span between the longitudinal girders. The dead and live loads are transferred to the arch ribs by 12 in. columns, heavily reinforced by 5/8 in. diam. rods, these columns being spaced at 10 ft. intervals. The details are shown on Plate 6. Special attention is called to the method of connecting the columns to the arch, such arrangement permitting the concrete of the arch to be placed without much interference from projecting rods.

The roadway of the approach is similar to that over the arch, but the longitudinal girders are 12 in. deep, 24 in. wide, and 14 ft. long. The dead and live loads are carried by columns 24 in. by 24 in., reinforced by 3/4 in. rods. The columns, except those at the arch haunches, rest on independent piers. The details are shown on Plates 2, 7, and 8.

The abutments are 22 ft. wide and sufficiently deep to distribute the loads from the arch ribs and the three approach columns, evenly over the foundations. The abutments rest on good rock foundation as do the independent column piers.

The hand-rail is of skeleton steel, consisting of 1-1/4 in. by 1-1/4 in. posts (spaced as shown in Plate 1) and 1-1/4 in. by 5/16 in. flats (as shown on Plate 8). It was the purpose to build in the future a concrete railing, and this steel would then act as the reinforcing.

Expansion joints 1 in. wide are provided in the masonry over both springing lines, but not at the crown. The joints were filled with tarred paper and have proven highly successful. The details are shown on Plates 1 and 2.

The gutters of the roadway were built level, but the drainage was taken care of by eight cast iron traps, connected to 3 in. pipe leading to the flower troughs. The provisions for drainage are shown on Plates 1 and 4.

The concrete used for all parts of the work, except the abutment foundations, was a 1;2-1/4:5 mixture made up of river sand, Lehigh Valley cement, and blue stone obtained from quarries along the upper Potomac River, eight miles from Washington. The abutment foundation was a 1:2-1/2:5 concrete mixture made up of the same kind of sand and cement, but broken brick was used in-

stead of stone. The District of Columbia owned some broken brick comparatively near the work and the substitution was made for the sake of economy.

The surface of the concrete was not tooled finished, as the natural surface was desired to give a more rustic appearance. The forms were removed as soon as considered practicable, in order that the board marks might be more easily and quickly effaced by the elements.

When the structure was first completed in 1907, the surface of the roadway was made of hard dirt instead of macadam, at the request of Ex.Pres.Roosevelt, for he considered the macadam harder on horses' feet. This dirt was replaced by macadam in 1909.

CHAPTER II

FACTORS INFLUENCING THE DESIGN

OLD STRUCTURE--There was built in 1890 by convict labor a trestle at this site, made up of white-oak bents, used as first cut in the woods, and a floor system of 3 in. by 16 in. timber, taken from one of the city bridges. The timber was in poor condition at the time a new bridge was first projected and would probably not have lasted five years longer. The engineers desired to use this trestle work, with additional bracing, as centering for a new bridge, and this was actually done. An accurate survey was made of the old structure, especially the location of the bents, and it was then seen that arch ribs could be built with little difficulty by making the center line of the new bridge 4 ft. 6 in. east of the old, with proper spacing of the outside ribs. Also, the flooring of the trestle could be used as forms for the slabs of the new floor system. This old structure furnished a roadway for transporting the materials, and obviated the necessity for any hoisting or other machinery, thus greatly reducing the cost of erection. It might be mentioned that the trestle was built originally by a practical foreman, from his own ideas conceived on the spur of the moment, without any written or drawn plans whatsoever.

DISTANCE FROM MATERIAL SUPPLIES--The bridge site is about

[illegible]

[illegible]

[illegible]

[illegible]

seven miles from supply depots, and the cost of hauling is very great compared to average construction works, the haul costing nearly twice as much as the market price of either sand or stone. It was therefore necessary to build as light a structure as possible to economize in material, compatible with the span and live loads required. The length of haul was not only great, but the last three miles was exceedingly hilly. One portion of the road for a distance of nearly half a mile has a nine percent grade, which factor alone required a four-horse team for that distance, for the average two-horse load.

FOUNDATIONS--The gorge showed many outcroppings of good rock and it was safe to assume that good foundations would be found at a shallow depth below the surface. Also, that some form of arch could be built where the stability of the foundations would be assured as well as the less liability of any appreciable settlement. The foundations of all the bridges in Rock Creek Park had been good and there was no indication that this particular site would be otherwise.

MAXIMUM LIVE LOADS--The bridge was to be designed for vehicular traffic alone, so it was not necessary to provide sidewalks. For this particular design, the traffic of the future would not change in character, no matter how rapid the development of the city. Steam rollers and traction engines are not allowed in the Park, so the heaviest load would be from large touring automobiles.

The maximum live loads were assumed to be 150 lbs. per sq. ft. of floor area for the arch ribs, and a concentrated load of 6 tons for the floor slab.

REGULATIONS OF ROCK CREEK PARK--The regulations require that all old trestle work must be replaced by structures more permanent in character whenever rebuilding is necessary. The Park is well policed and the traffic is absolutely regulated so far as the elimination of heavy city loads is concerned. There is also a rule that no stone, sand, or material of any description shall be used from the resources of the Park; and therefore all necessary materials must be brought from without its limits. When building bridges or other structures special permission must be obtained from the War Department to remove trees and such directly in alignment, as well as for the use of trees in bracing guy lines.

NATURAL BEAUTY OF SURROUNDING PARK--This particular site is in a thickly wooded gorge that has no semblance of artificiality. The vistas from roads further down the valley required as light a structure as possible, so as not to obstruct the view; and the picturesqueness required some treatment that would blend most harmoniously with the surroundings. The trees are thick and of many varieties, and the outcropping boulders are covered with moss and clinging vines. The structure to meet the conditions should be left rough, having columns resting on the arch, and the whole appearance should be what might be termed subdued.

ECONOMY--The sum of money allowed for building the bridge was very small in comparison to the span necessary and the structure desired. The annual appropriation for Rock Creek Park was $20,000 and out of that comes the repairs to roads and bridges, the construction of new roads, bridges and culverts, and miscellaneous expenses in the way of salaries. $7,000.00 was the max-

imum allowed for Ross Drive Bridge, and a very light masonry bridge was necessary in order not to exceed that sum.

THEORY OF THE ARCH--The methods of analyzing an arch are more or less approximate as acknowledged by the best writers on the subject, and the exact distribution of stresses at the haunches and throughout the arch ring can not be found. Even though the methods of analyzing are theoretically correct, the method of building the arch may entirely change the point of concentration of the thrust at the haunch, and thereby upset previous calculations. The use of lead joints does not do away with this latter objection. An analysis of the same arch by several well-known methods, will give entirely different results. It was then seen to be desirable in building such a light structure, where the maximum safe strength of the material might be taken advantage of, to use some three-hinged arrangement whereby the stresses can be more accurately determined. The analysis of a masonry arch with steel hinges and concentrated loads is as accurate as a steel hinged arch. Although a three-hinged pin-connected masonry arch had never been built in America, there are two in Europe that have proven highly successful.

CHAPTER III

DESIGN OF THE ARCH RIBS

METHOD OF DESIGN--The design of the arch ribs was made entirely from an engineering standpoint, and the appearance probably would not be considered in good form by an architect. Yet since the bridge has been completed the engineers have received praise on the general artistic impression of the structure as a whole.

After the decision had been reached to build the arch three-hinged, the positions of the three points were determined from conditions of the rock footings, the slope of the ground, and the elevation of the roadway. Then the entire superstructure above the arch including the spacing of the columns was designed and the dead loads calculated. Likewise the live loads were calculated. It was seen, as shown in Chap. V, that the inside arch rib carried the heaviest loads, and as the three ribs were to be similar in dimensions, the inside rib was used for analysis. A curve of pressure for dead load alone was drawn through the three points, using the Rational Theory as advocated in Baker's Masonry Construction. Curves of pressure were also drawn for dead load plus live load on roadway over the right half of arch; also curves for live load over the left half. Cross sections were assumed at the crown and haunches with the maximum pressure at

these points to be 400 lbs. per sq. in. An arch rib was now sketched in, whereby there should be no tension at any joint and the curves should not pass out of the middle third. Re-calculations were made taking the weights of the arch ring into consideration. The first arch ring assumed was then seen to be slightly wrong, and a new one was assumed. After three trials, the arch ring as used fulfilled the required conditions.

With the unsymmetrical live load over the right half of the arch, the curve of pressure just touches the outside limits of the middle third at joints 1 and 3 on the left half of the arch, and gave higher compressive stresses than desired, viz., 678 lbs. per sq.in. at joint 1. Steel rods used to hold the pin shoes in position were placed in the arch rib at top and bottom, and extended beyond joint 3, in order to reduce this high stress to about 500 lbs. per sq. in. on the concrete. The final arch rib was 2 ft. wide, 2 ft. 6 in. deep, at the crown and 3 ft. deep at the haunch, while the rib measures 3 ft. 9 in. at a point 18 ft. from the haunch.

The Elastic Theory was not used to check the results as the engineers believed that the rational method was equally as good and the stresses determinate, when using a three-hinged arch. The chief advantage of the Elastic Theory is the fixing of the curve of pressure, whereas by using three pin hinges the curve is absolutely fixed by the rational analysis with fewer calculations.

The pressure at the joints were found by the following well-known formula from Baker's Masonry Construction:

$$P = \frac{W}{l} + \frac{6Wd}{l^2}$$

P=maximum pressure on the joint per unit of area.

W=normal pressure on the joint per unit of length of the arch.

l=depth of the arch joint.

d=distance from the center of pressure to the middle of the joint.

<u>UNIT</u> <u>LOADS</u>--The following unit loads were assumed:

Reinforced concrete............	150	lbs. per cu.ft.
Unreinforced concrete.........	150	" " " "
Macadam paving................	100	" " " "
Steel.........................	490	" " " "
Live load.....................	150	" " sq." of roadway.

CHAPTER IV

LOADS ON ARCH RIBS

ARCH RING:

Total Weight

Block 1=(see Plate 10) $\frac{2.5+2.75}{2}$ x 10 x 2 x 150= 6800 lb.

" 2=$\frac{2.75+3.5}{2}$ x 10 x 2 x 150 = 9400 "

" 3=$\frac{355+3.9}{2}$ x 10 x 2 x 150 =11200 "

" 4=$\frac{3.9+3.9}{2}$ x 10 x 2 x 150 =11800 "

" 5=$\frac{3.9+3.5}{2}$ x 10 x 2 x 150 =11200 "

ARCH STRUTS:

1st. Strut = .5 x (3.0+3.0+2.0) x 150 = 600 lbs. per lin.ft.

2nd. Strut = .5 x (3.75+3.75+2.0)x150 = 730 " " " "

COLUMNS:

Column 1=(see Plate 10) = 1 x 1 x 2.25 x 150 -= 340 lb.

" 2= 1 x 1 x 3.0 x 150 = 450 "

" 3= 1 x 1 x 4.75 x 150 = 710 "

" 4= 1 x 1 x 8.25 x 150 = 1240 "

" 5= 1 x 1 x 13.75 x 150 = 2060 "

PIN SHOES:

Shoe at the crown = $\frac{1260}{1728}$ x 490 = 360 each half

" " " haunch= $\frac{1675}{1728}$ x 490 = 475 " "

LONGITUDINAL GIRDERS:

12" x 12" = 1 x 1 x 150 = 150 lbs. per lin. ft.

FLOOR SLAB:

.5 x 1 x 150 = 75 lbs. per sq.ft.

COPING:

2.625 x 1 x 150 = 390 lbs. per lin.ft.

HANDRAIL:

1-1/4"x 1-1/4" post= 5.3 x 4.0 = 21 lbs. each

1-1/4"x 5/16" flats= 1.33 x 3 = 4 lbs. per lin.ft.

MACADAM PAVING:

.5 x 1 x 100 = 50 lbs. per sq.ft.

LIVE LOADS:

150 lbs. per sq. ft. of roadway.

CHAPTER V

DISTRIBUTION OF LOADS CARRIED BY ARCH RIBS

INSIDE ARCH RIB:

Dead Load per Column(Cols. spaced 10 ft. apart)			
Floor slab = 75 x 10 x 8	=	6000	lbs.
Floor surface = 50 x 10 x 8	=	4000	"
Longitudinal girders = 150 x 10	=	1500	"
Total	=	11500	"
Live Load per Column			
150 x 10 x 8	=	12000	"
Total Dead and Live Load per Column	=	23500	"

OUTSIDE ARCH RIB:

Dead Load per Column(Cols. spaced 10 ft. apart)			
Floor slab = 75 x 10 x 3	=	2250	"
Floor surface = 50 x 10 x 4.5	=	2250	"
Longitudinal girder = 150 x 10	=	1500	"
Coping = 390 x 10	=	3900	"
Handrail = 22 x 10	=	220	"
Total	=	10020	"
Live Load per Column			
150 x 10 x 4.5	=	6750	"
Total Dead and Live Load per Column	=	16770	"

From the preceding calculations, it is seen that each column on the inside arch rib carries more dead and live loads than does one on an outside rib. As the arch ribs are made exactly similar, the inside arch rib is stressed higher than either of the outside.

CHAPTER VI

STRESSES IN THE ARCH

ANALYSIS BY RATIONAL THEORY

DEAD LOAD OF ARCH RING:--The analysis was made for a section of the arch ring 1 ft. wide. The loads used were as follows

$$\text{Block 1} = \frac{2.5+2.75}{2} \times 10 \times 1 \times 150 = 3900 \text{ lbs.}$$
$$\text{" } 2 = \frac{62.75+3.5}{2} \times 10 \times 1 \times 150 = 4700 \text{ "}$$
$$\text{" } 3 = \frac{3.5+3.9}{2} \times 10 \times 1 \times 150 = 5600 \text{ "}$$
$$\text{" } 4 = \frac{3.9+3.9}{2} \times 10 \times 1 \times 150 = 5900 \text{ "}$$
$$\text{" } 5 = \frac{3.9+3.5}{2} \times 10 \times 1 \times 150 = 5600 \text{ "}$$

The center of gravity of each block was found by cutting out a piece of card-board to scale the same size of the block, and then balancing the card-board on a pin point. This method takes time, yet is very efficient.

The curve of pressure is shown on Plate 10 and is seen to lie approximately in the center of the arch rib.

$$\text{Pressure at the crown} = \frac{41000}{30 \times 12} = 114 \text{ lbs. per sq.in.}$$
$$\text{" " " haunch} = \frac{48300}{36 \times 12} = 112 \text{ " " " "}$$

The pressures at intermediate joints are even less than those at the crown and haunch.

DEAD LOAD OF ARCH RING AND SUPERSTRUCTURE--The analysis is shown on Plate 10. The same loads for the arch ring in the preceding analysis were used, and in addition the weights of the

struts, columns, and superstructure as found in Chaps. IV and V.

The order of the application of the concentrated loads, beginning at the crown, was as follows:

Column 1	5900 lbs.
Block 1	3900 "
Column 2	6000 "
Block 2 and Strut	6500 "
Column 3	6100 "
Block 3 and Strut	7800 "
Column 4 and Block 4	12300 "
Block 5	5600 "
Column 5	6800 "

The line of pressure is seen to stay approximately in the center of the arch rib. The pressures are practically uniform and are not excessive.

Pressure at the crown $= \frac{103500}{30 \times 12} = 285$ lbs. per sq.i

" " " haunch $= \frac{120000}{36 \times 12} = 285$ " " " "

<u>DEAD LOAD OF ARCH RING, SUPERSTRUCTURE AND FULL LIVE LOAD</u>--The dead loads used were the same as in the preceding analysis, with the addition of 6000 lbs. to each column load. The analysis is shown on Plate 11. The curve is seen to be approximately in the center of the arch ring, and the unit pressures are practically uniform. This loading gives the maximum pressures for the crown and haunch.

Pressure at the crown $= \frac{152000}{30 \times 12} = 420$ lbs. per sq.in.

" " " haunch $= \frac{176000}{36 \times 12} = 408$ " " " "

<u>DEAD LOAD OF ARCH RING, SUPERSTRUCTURE AND UNSYMMETRICAL LIVE LOADS</u>--Two pressure curves were drawn, one for the live load

over the right half of arch, and the other for live load over the left half. The analysis is shown on Plate 11. This method of loading gives maximum pressures for all joints except the crown and haunch.

$$\text{Pressure at crown} = \frac{127500}{30 \times 12} = 352 \text{ lbs. per sq.in.}$$

$$\text{" \quad " haunch} = \frac{152500}{36 \times 12} = 352 \text{ " \quad " \quad " \quad "}$$

The pressure at the joints was found by the formula $P = \frac{W}{l} \quad \frac{6Wd}{l^2}$ as explained in Chap. III.

The following table gives the pressures at the different joints for unsymmetrical live loads:

Joint	W lbs.	l in ft.	d in ft.	Max. Stress (lbs.per sq.in.) Intrados	Extradose
1	128000	2.55	0.40	+ 18	+678
	127500		0.15	+488	+208
2	128500	3.1	0.50	+ 10	+566
	129500		0.45	+542	+ 38
3	133000	3.6	0.60	0	+512
	132000		0.60	+508	0
4	135500	3.75	0.50	+ 51	+451
	134500		0.55	+469	+ 29
5	145000	3.45	0.30	+140	+444
	141500		0.15	+360	+210

+signifies compression.

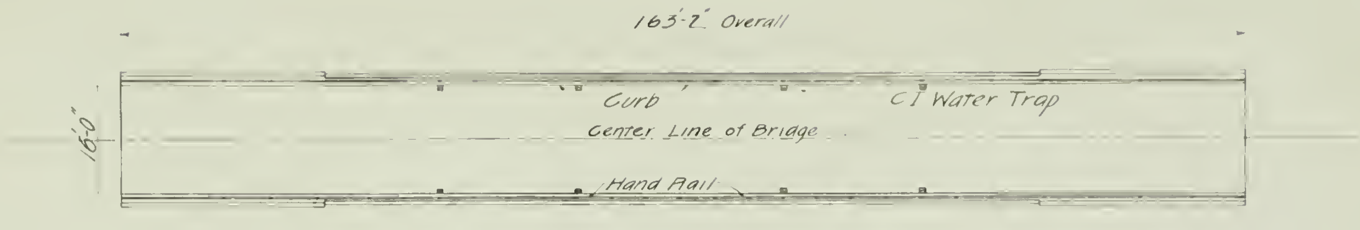
CHAPTER VIII

ESTIMATE OF COST

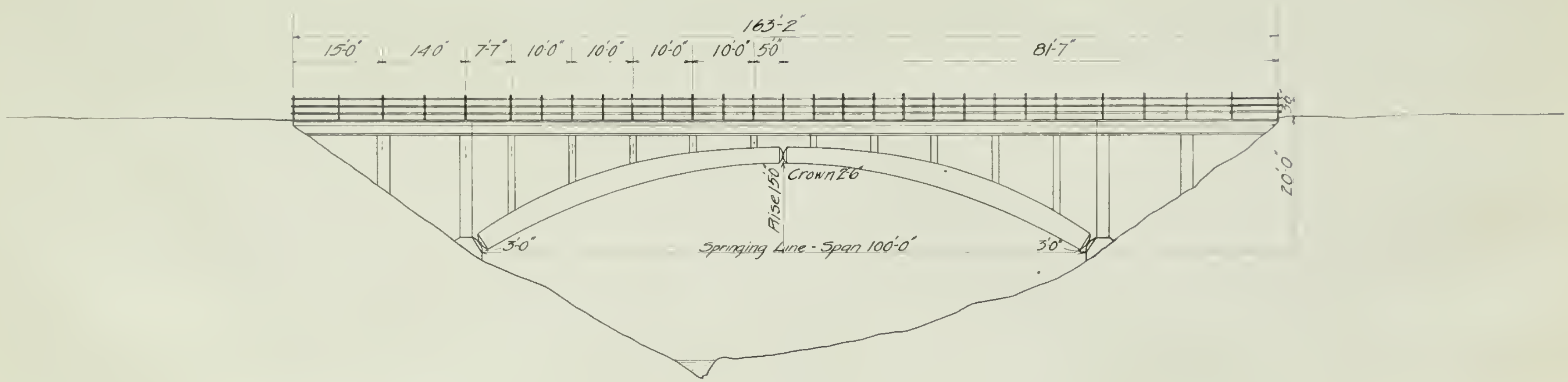
The material for the bridge was obtained from the District of Columbia supply yards, except the pins, pin-shoes, reinforcing and railing, which were procured from the lowest bidder by special contract. The labor was furnished by the regular District of Columbia bridge repair gang working under their regular foreman. The material and labor cost more than ordinary, due to the distance of the bridge site from the center of the city. The cost of hauling for stone and sand was $2.00 per load of 1-1/2 cu.yds; for cement, 20¢ per bbl.; and the other material in a like proportion. The laborers were paid 25¢ extra per day for car-fare, and their working hours were shortened by much loss of time in going to and from the city, the men being paid on a per diem basis. Yet the total cost of the bridge, $6083.63, is remarkably small, when considering the length over all, the square feet of roadway and the length of span. The cost is $37.30 per lin. ft. of bridge, or $2.33 per sq.ft. of roadway.

The details of cost are as follows:

Steel		
Bolts and nuts	$ 49.88	
Hinges, pins and castings	626.10	
Reinforcing steel	595.89	
Drain pipes	4.32	
Railing	149.00	$ 1,425.19
Labor		2,987.29
Lumber and nails		344.00
Sand		77.40
Stone and broken brick		391.96
Cement		570.00
Engineering 5%		289.79
Total Cost		$ 6,085.63



Plan

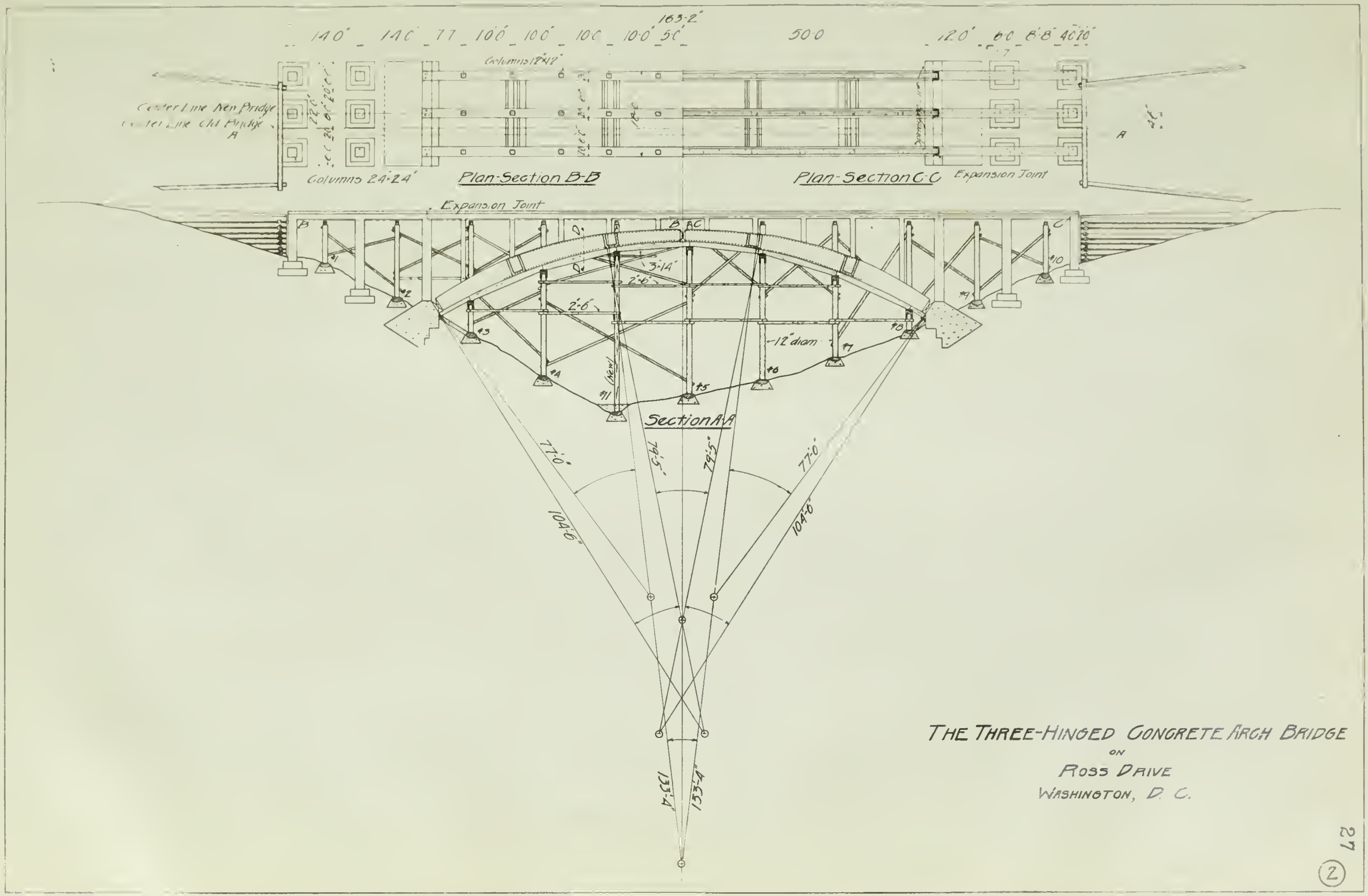


Side Elevation

THE THREE-HINGED CONCRETE ARCH BRIDGE
ON
ROSS DRIVE
WASHINGTON, D. C.

26

(1)



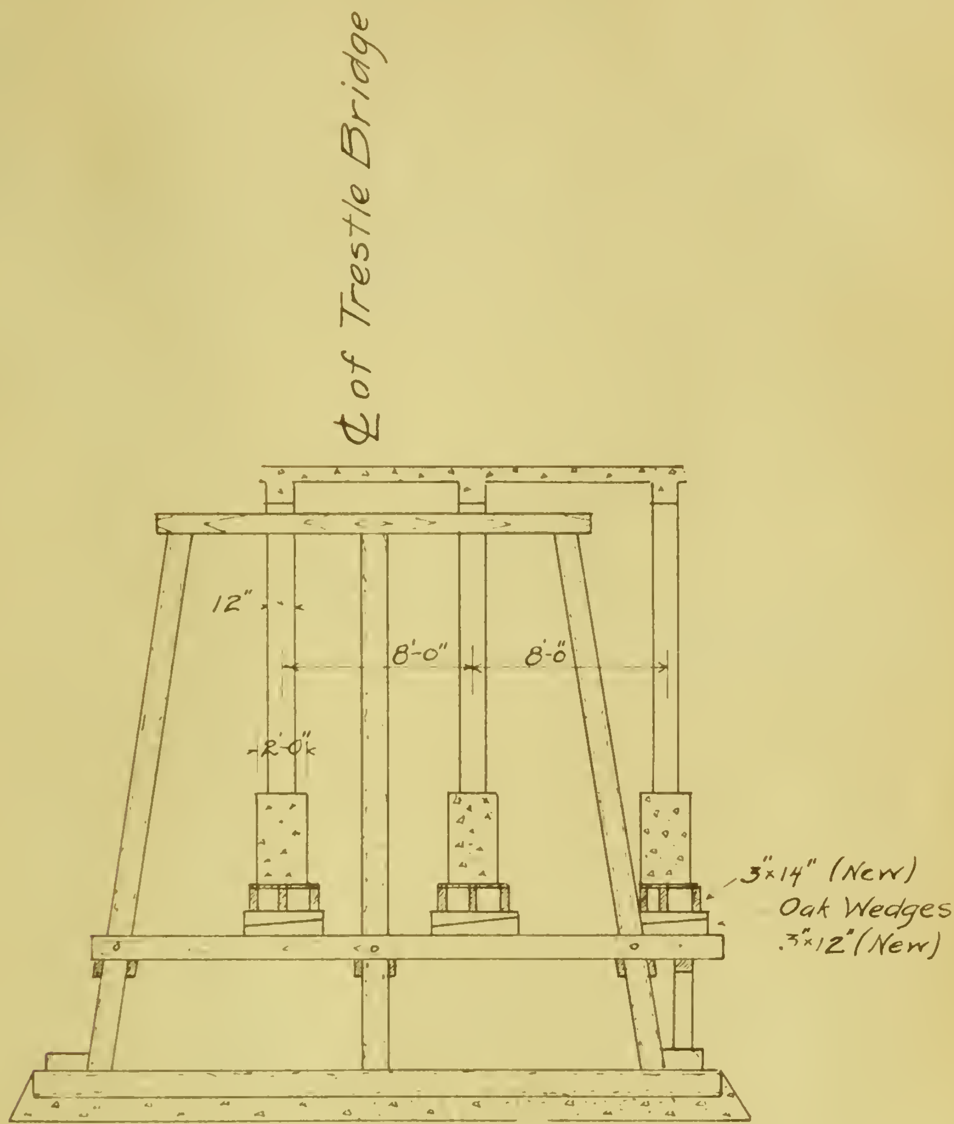
THE THREE-HINGED CONCRETE ARCH BRIDGE

ON

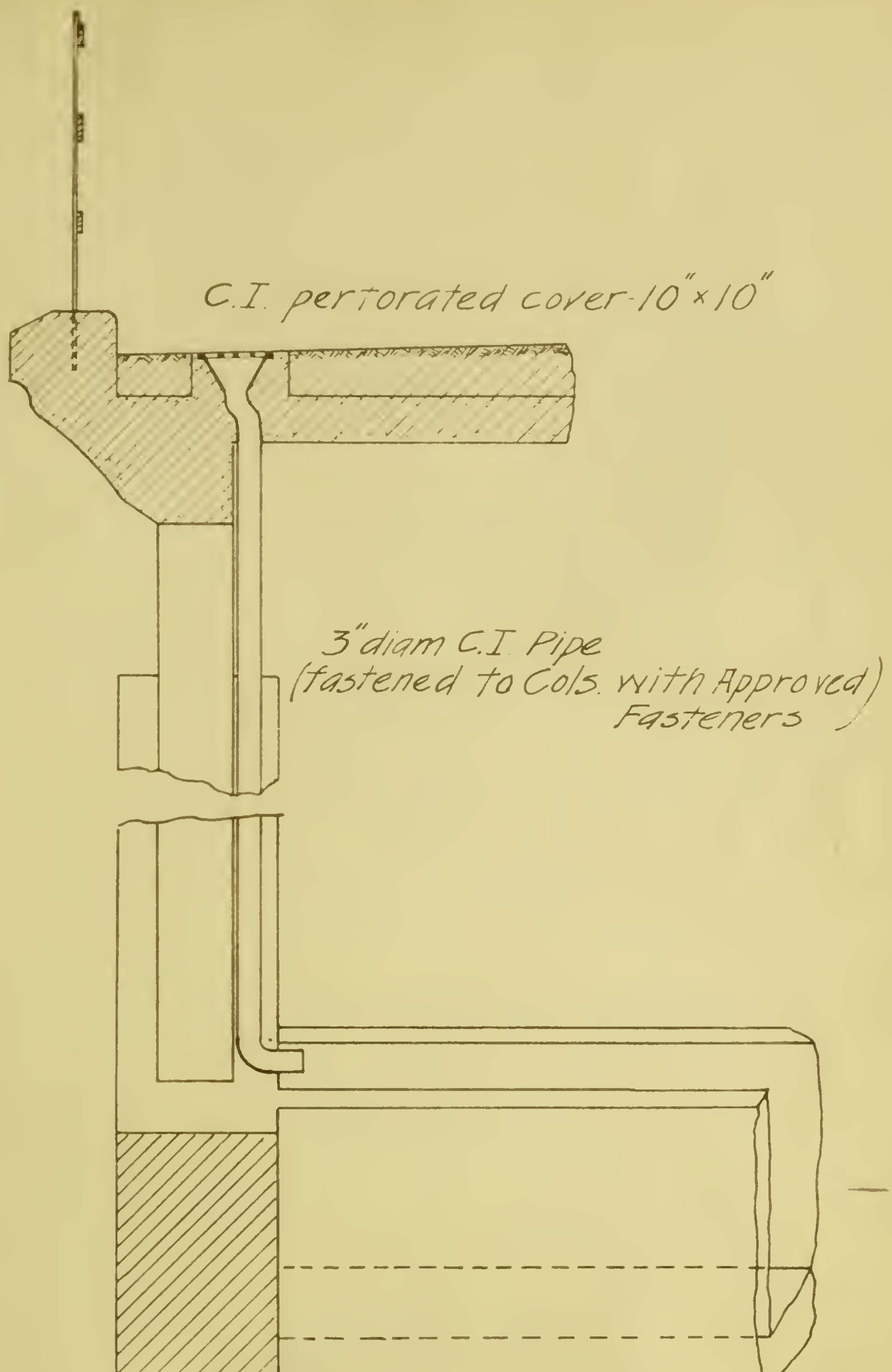
ROSS DRIVE

WASHINGTON, D. C.

(2)



Bent No. 3

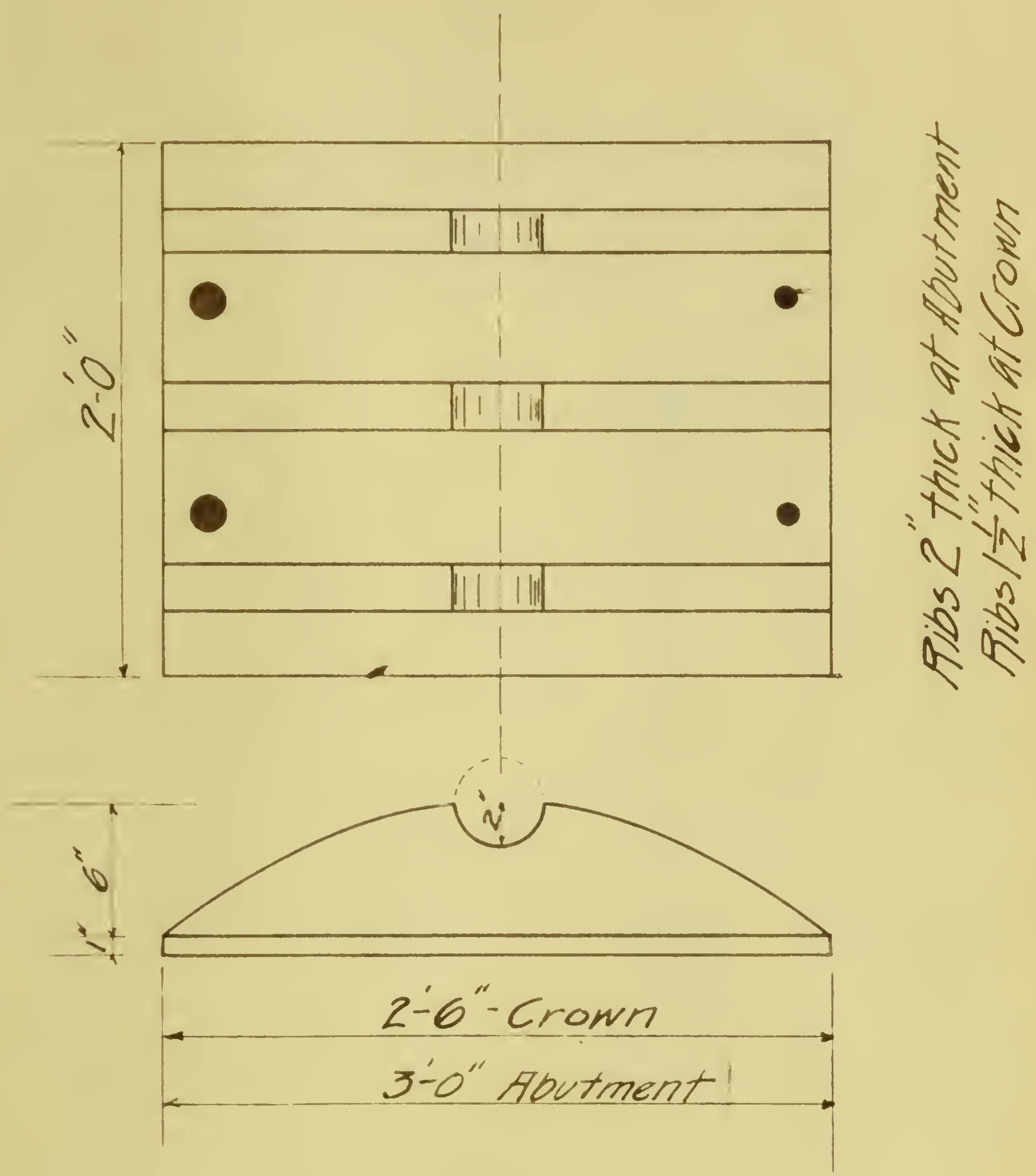


Section at C.I. Trap and Down-spout
Scale ½"=1'-0"

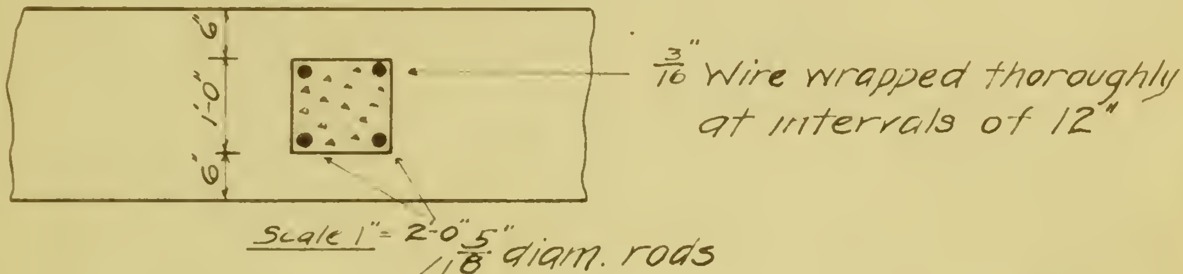
4

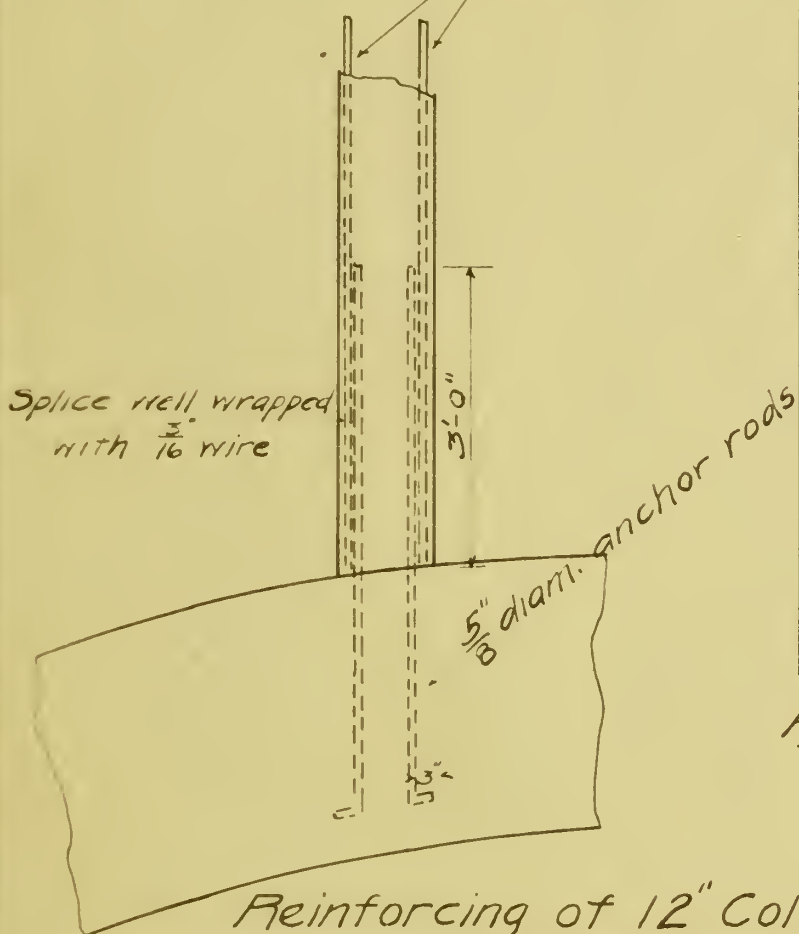
Abutment $1\frac{3}{16}''$ holes
Crown $1\frac{5}{16}''$ holes

Abutment and Crown $\frac{13}{16}''$ holes

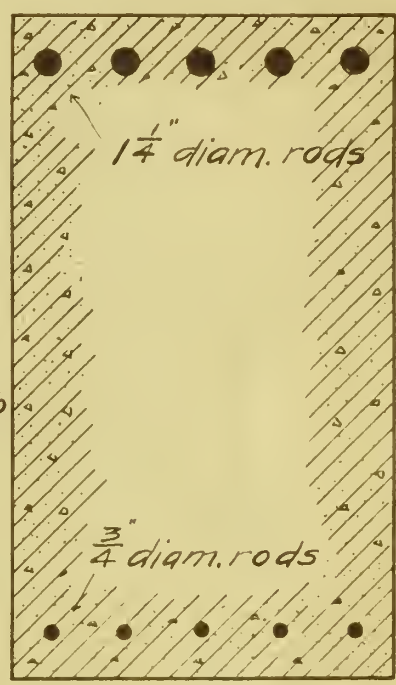


Detail of Hinges





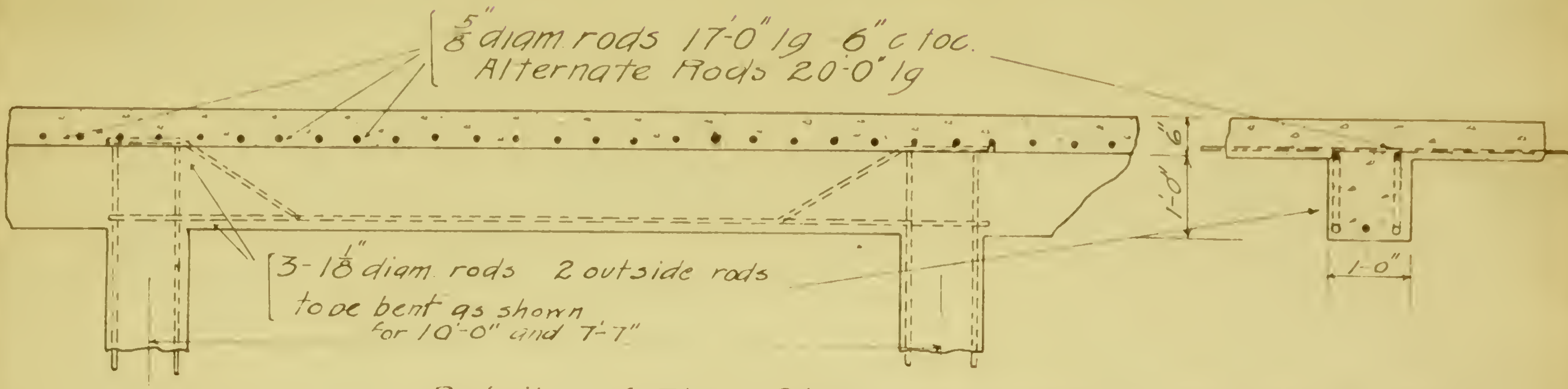
Reinforcing of 12" Columns



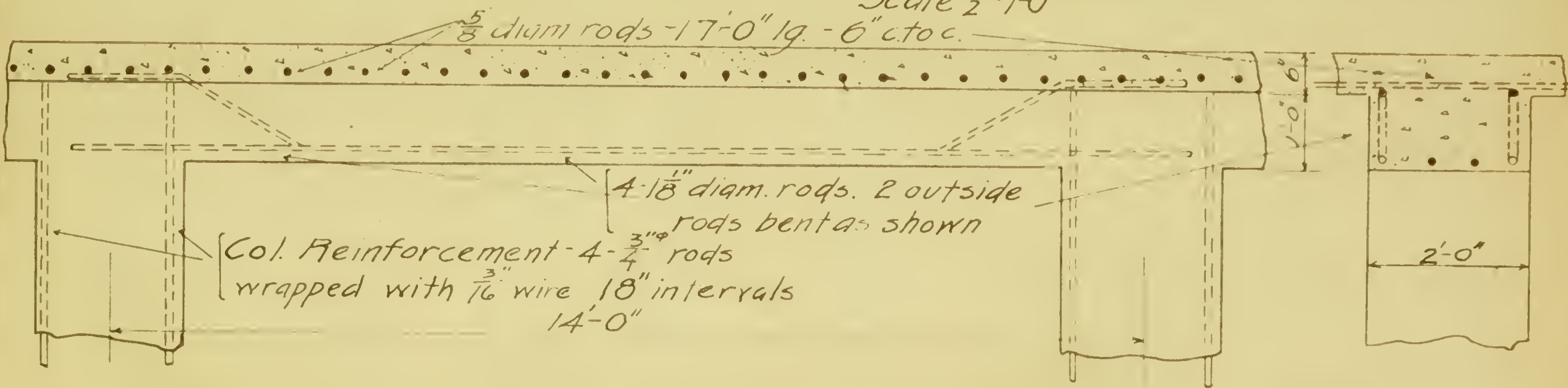
Arch Reinforcing

Section D-D

Scale 1" = 1'-0"



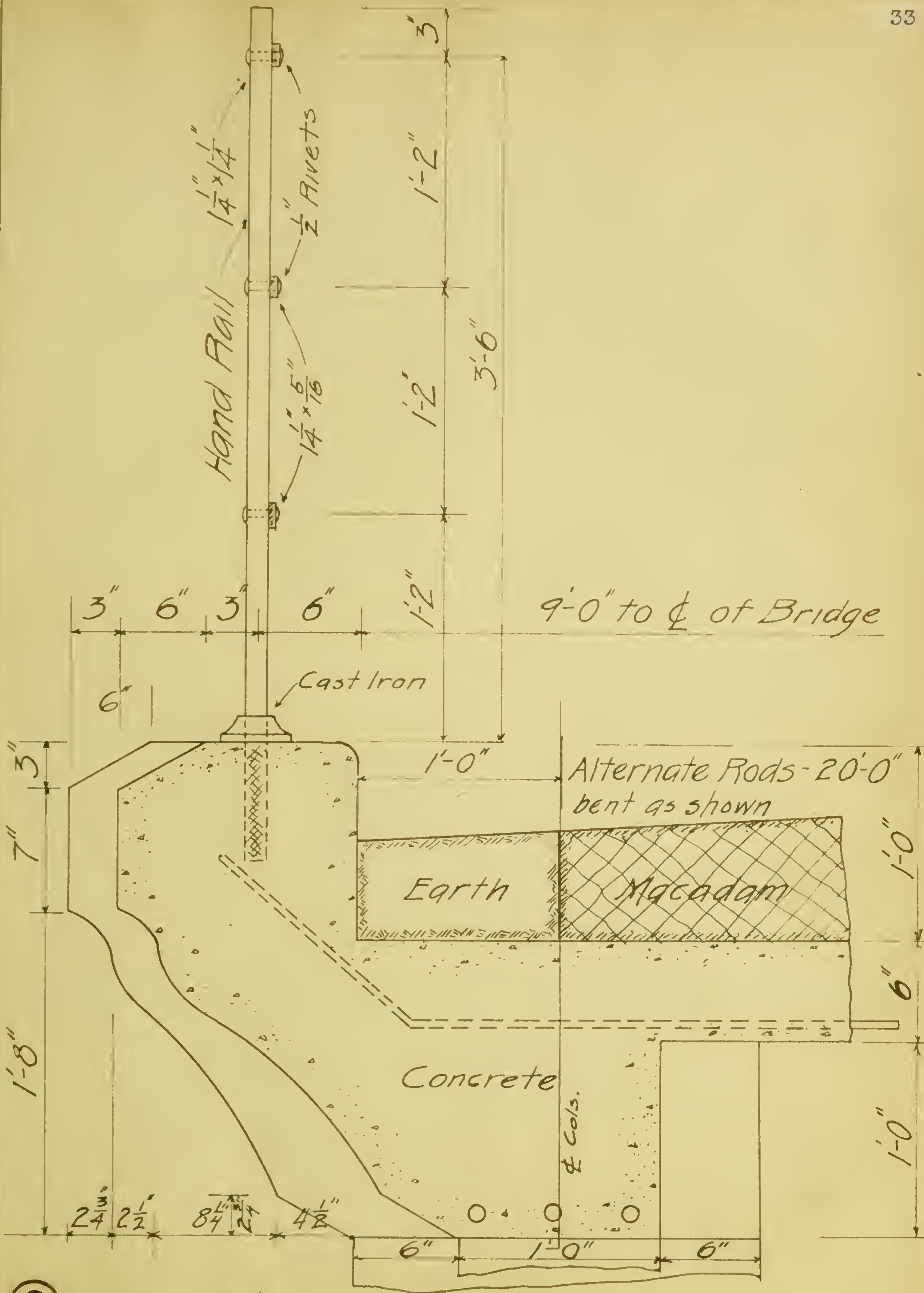
Details of Floor Slab and Girders over Arch Ribs
Scale 1/2" = 1'-0"



Detail of Girders, Approach
Scale 1/2" = 1'-0"

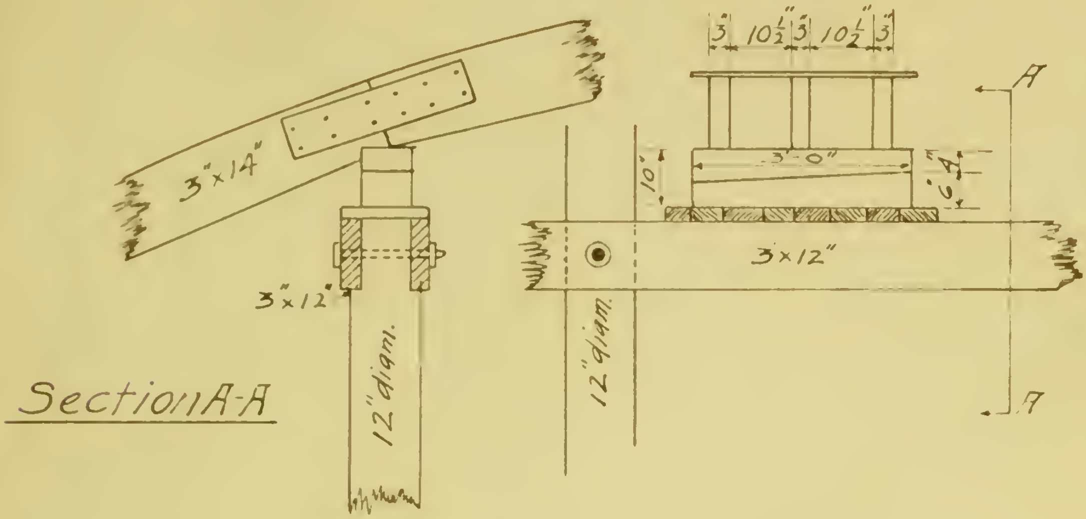
7

32

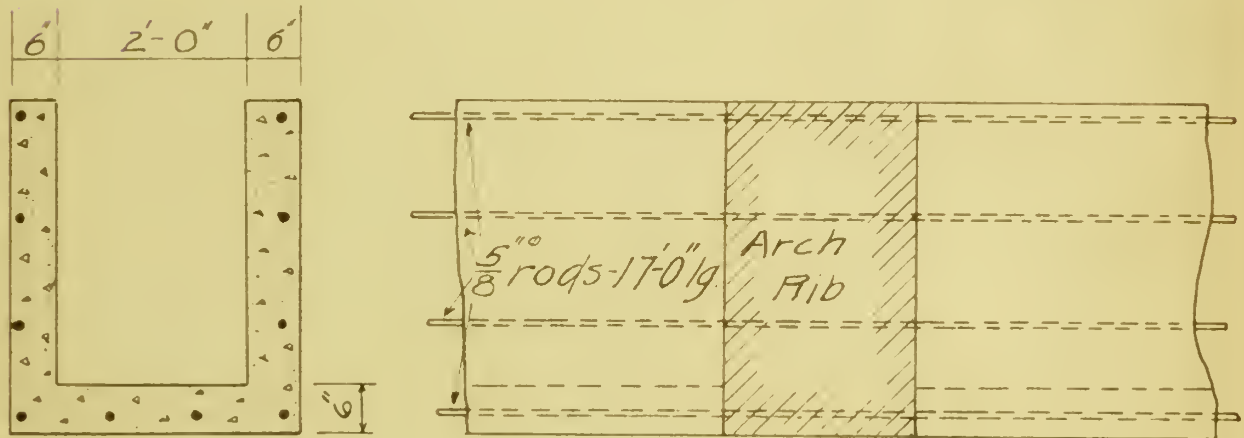


Section of Roadway over Arch

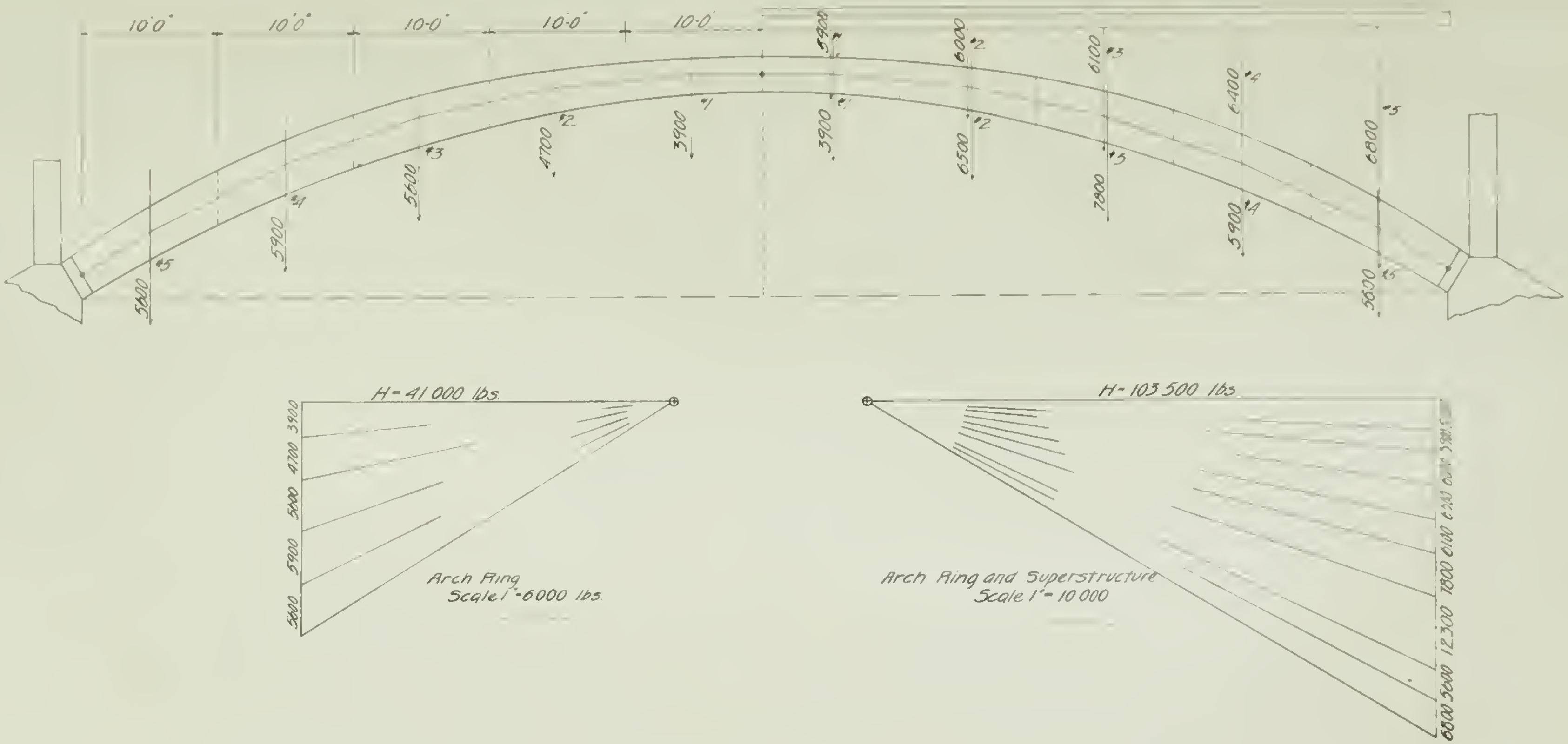
Scale $1\frac{1}{2}" = 1'-0"$



Detail of Wedges
Scale 3/8" = 1'-0"

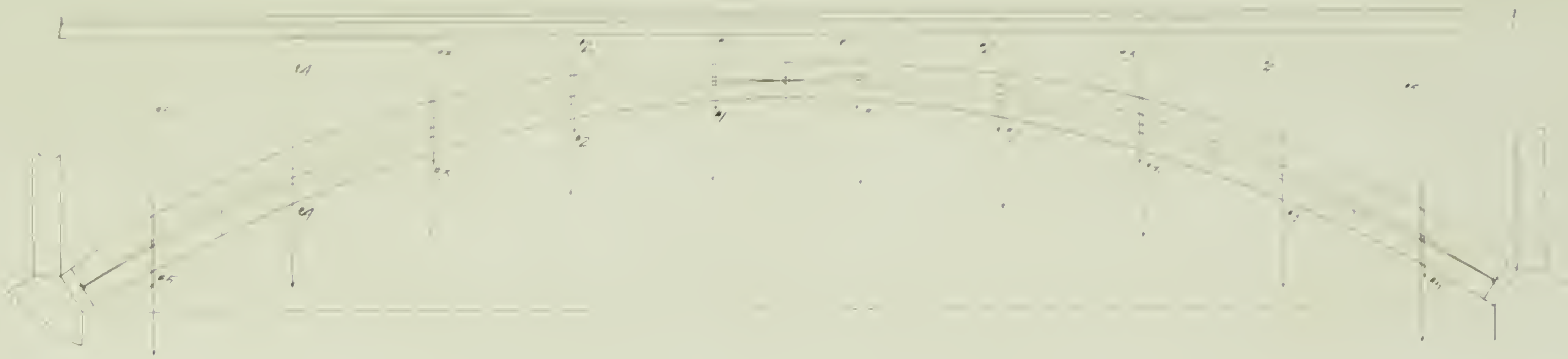


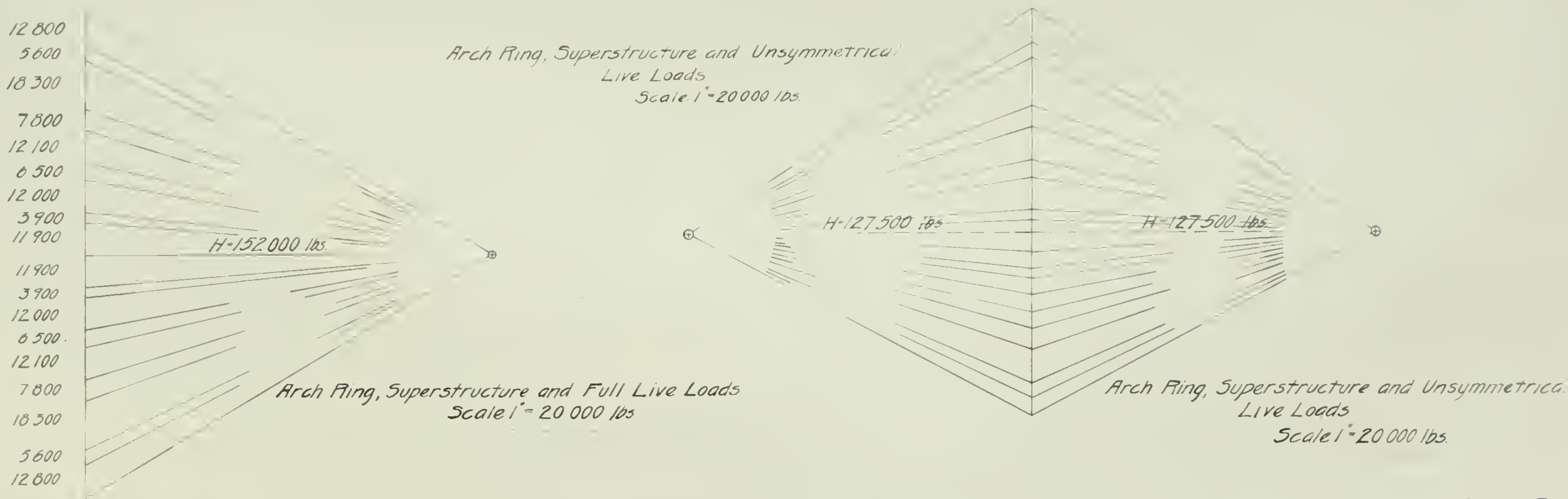
Detail of Flower Troughs
Scale ½" = 1'-0"



Note
Calculations are based on a longitudinal section of Arch Rib 1 ft. wide
Masonry in columns, arch ring, and girders---150 lbs per cu. ft
Macadam paving---100 lbs. per cu. ft.

THE THREE-HINGED CONCRETE ARCH BRIDGE
ON
ROSS DRIVE
WASHINGTON, D. C.





Note:-

Calculations are based on a longitudinal section of Arch Rib 1 ft. wide
Masonry in columns, arch ring and girders ··· 150 lbs per cu. ft.
Macadam paving ··· 100 lbs. per cu ft
Live load ··· 150 lbs per sq. ft.

THE THREE-HINGED CONCRETE ARCH BRIDGE
ON
ROSS DRIVE
WASHINGTON, D. C.